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Notes and Comments

A Comment on: The Instantaneous Center of Rotation During Human Jaw Opening and Its Significance in Interpreting the Functional Meaning of Condylar Translation (Chen, X., 1998, Am J Phys Anthropol 106:35–46.)

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Chen (1998) recently published the results of a study in which he recorded movement of the mandible during jaw opening in seven human subjects. From these data, Chen (1998) claims to have determined the location of the instantaneous center of rotation (ICR) of the human mandible using a two-dimensional algorithm for ICR determination (Crisco et al., 1994).

Chen's (1998) study suffers from several methodological problems, and most likely resulted in an incorrect location for the ICR. This paper discusses three significant shortcomings of Chen's (1998) analysis that concern the method of determining the location of the ICR. We conclude with a discussion of the mechanical implication of Chen's (1998) determination of the ICR.

Location of the ICR

There are at least three major problems with Chen's (1998) methodology. Most significantly, the limitation of using two-dimensional light photography constrained reconstruction of the ICR as a two-dimensional coordinate. Chen (1998) discusses the large errors in locating the ICR from two-dimensional data. While the use of the algorithm of Crisco et al. (1994) reduces these errors, as Chen (1998, p. 39) notes, they are still considerable. Chen (1998), in his discussion of Grant (1973) and Gibbs (1969), implies that his approach provides the best available data on ICR location in humans during jaw opening. A recent publication of the location of the ICR in three dimensions (i.e., as an axis) during jaw opening and closing in 30 human subjects by Gallo et al. (1997), however, eliminates the need for inaccurate, two-dimensional ICR reconstructions. Therefore, we believe that the data from the Gallo et al. (1997) study provides a more reliable location for the ICR than the Chen (1998) study.

Gallo et al. (1997) digitally recorded the jaw opening and closing movement and combined these data with MRI images of the TMJ to reconstruct the ICR and derive its distance from the condyle. Although Chen (1998, pp. 39–40) cites a paper on condylar sliding in humans by Merlini and Palla (1988) and writes that they are "using a more sophisticated condylar tracking device," he appears to be unaware of the Gallo et al. (1997) study, which employs the same tracking device.

Gallo et al. (1997) found that the average mandibular rotation about the ICR was 24.3°. This result is comparable to the maximum angular gapes recorded by Chen (1998). Gallo et al. also found a fair amount of variability in the distance between the condyle and the ICR. This, too, was found by Chen. However, the reconstruction of ICR locations in Gallo et al. are markedly different from those of Chen. For example, Gallo et al. found that the average distance between the ICR and the mandibular condyle was 48.9 mm (±9.9 mm). As the height of the ascending ramus of the adult human mandible is typically between 45 and 60 mm, the findings of Gallo et al. indicate that the ICR is frequently near the lower border of the mandible in the gonial region (Fig. 1). In

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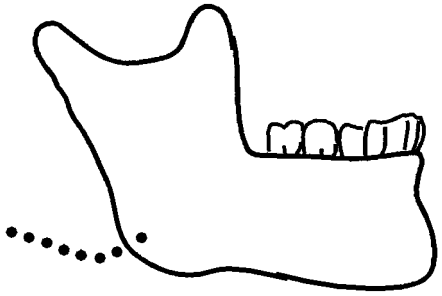

Fig. 1. A reconstruction of the approximate path of the axis of mandibular rotation during jaw opening based on the results of Gallo *et al.* (1997).

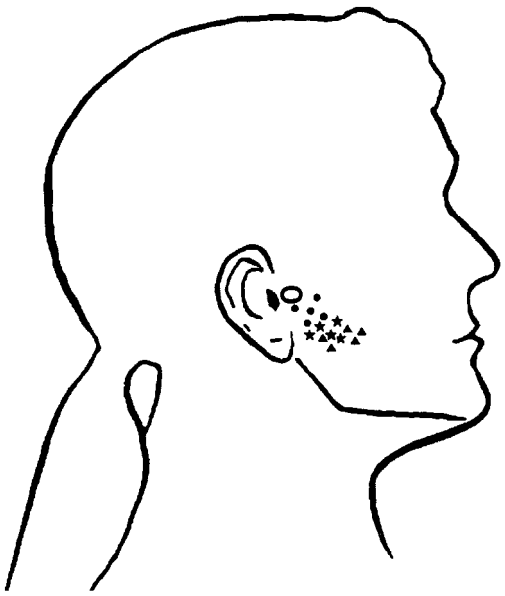

Fig. 2. A reproduction of Chen (1998: p. 40, Fig. 5) showing the *anterior* position of the ICR relative to the mandibular condyle during the first 10° of rotation in four of the five jaw opening movements (closed circles). Our determination of the location of the mandibular condyle is denoted by an open ellipse. The triangles indicate the ICR location for the rest of the rotation. The stars indicate the average ICR location for each opening movement. Note that all of the points are in the superior half of the ascending ramus and that many are in the region of the sigmoid notch.

marked contrast, Chen found that the ICR was concentrated in the superior half of the ascending ramus, frequently in the region of the sigmoid or mandibular notch (Fig. 2).

A second problem, also of considerable significance, is that Chen (1998) had his subjects apply an extraneous external force (unmeasured and uncontrolled) to their mandible in order to hold the movement-tracking apparatus in place on the anterior surfaces of the mandibular incisors. This force was applied by both of the subject's index fingers, which were pressed against a piece of surgical wire that in turn was pressed against the anterior surfaces of the incisors. We suspect that this external force altered the path of motion of the mandible during jaw opening, and therefore the location of the ICR. The use of this type of error-prone "device" and procedure is puzzling given that light-weight orthodontic brackets for rigidly (and temporarily) attaching movement-tracking devices to the teeth are readily available (e.g., Gerstner and Parekh, 1997).

A third problem is that Chen (1998) *estimated* the position of the condyle for each subject from externally visible facial landmarks. This method of locating the condyle is likely very imprecise and has important consequences for interpreting Chen's results (see below).

Mechanical implication of Chen's (1998) results

Unfortunately, Chen (1998) did not list the facial landmarks used to estimate condylar position, and condylar position relative to the ICR is critical for understanding the mechanical implication of his results. In humans, the mandibular condyle is immediately anterior to the external opening of the external auditory meatus (EAM). This can be easily demonstrated by placing the tip of your index finger into the external opening of your EAM, opening your mouth, and feeling the condyle move anteriorly from its position in front of the EAM. Since Chen (1998) illustrates the external opening of the EAM for each subject, we have used that landmark to interpret his figures.

In two of the seven individuals shown in Fig. 4 (Chen, 1998, p. 40), the averaged ICR for the first 10° of rotation is *anterior* to the condyle.[1] Five opening movements are shown for an individual in Figure 5 (Chen, 1998, p. 40 and also reproduced here as Fig. 2). The averaged ICR for the first 10° of rotation for

[1]In a third individual, it is superior to the condyle indicating the unlikely event that the condyle was sliding posteriorly during the opening movement.

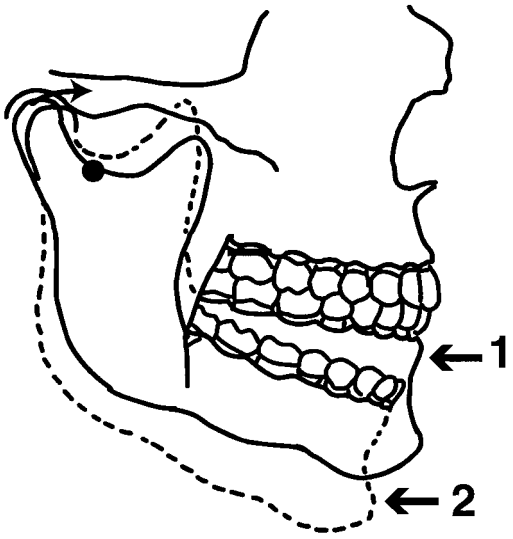

Fig. 3. Position 1 is the location of the mandibular condyle when the teeth are in occlusion. Position 2 is the location of the mandibular condyle relative to the articular eminence after about 10° of rotation when the ICR is posterior and inferior to the condyle. If the ICR is anterior to the condyle during the first 10° of rotation (as shown here by the large closed circle in the region of the sigmoid notch), the condyle moves anteriorly and superiorly through the bone of the articular eminence (as indicated by the arrow). This is not mechanically possible without shattering the articular eminence or condyle.

this individual is *anterior* to the condyle in four of the five opening movements (Fig. 2). However, in the text, Chen (1998, p. 39) writes that "for the first 10° of natural opening, ICRs are scattered largely inferiorly and *posteriorly* (emphasis added) to the condyles." Chen needs to resolve this discrepancy. This is important because, as shown here in Figure 3, Chen's (1998, p. 40) illustrations suggest that, during the first 10° of rotation in some of the jaw opening movements, the condyle passed through the bone of the articular eminence. This is not mechanically possible unless we posit that either the articular eminence or the condyle shattered during jaw opening in two of the subjects.

In summary, we believe that the location of the ICR relative to the mandibular condyle was not correctly identified by Chen (1998). In contrast, the study by Gallo et al. (1997) demonstrates that the ICR during jaw opening is located well away from the mandibular condyle, in the general area of the gonial region. These results, which are based on a more accurate methodology, should be accepted as the best information on ICR location during jaw opening in humans to date. Ironically, the results of Gallo et al (1997) are more similar to those of Grant (1973) and Gibbs (1969) than they are to those of Chen (1998).

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